Mapping the hydropower resource of the Yangtze River drainage basin

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Abstract

Hydropower is an important component of China's energy mix and this paper summaries work to model and map potential hydropower within the Yangtze drainage basin. To date most of the work has been in development of hydrological modelling over a long time series from 1979 to 2007. Calibration and optimisation of the model on a small sub-catchment of the Yangtze has shown strong correlation between modelled and observed flow duration curves. The outputs from the hydrological modelling will feed into the hydropower search which is still under development. Importantly, the input data sources are publicly available and hence the techniques could be employed on any global catchment.

1 Introduction

Development of low carbon renewable resource is desirable to mitigate future global-warming. Hydropower remains the most important of renewables for electricity production contributing more than the sum of other renewables and nuclear together (BP, 2015). Small scale hydropower, particularly "run of river" is considered one of the most cost-effective and environmentally benign energy technologies and can provide a significant resource and provide power to rural communities off-grid (Paish, 2002).

Due to massive economic growth in China coupled with increasing energy consumption, alternatives to fossil fuels are essential for future sustained growth and to mitigate climate change. China generates almost 25% of global renewable energy but also consumes 23% of world primary energy (BP, 2015*)* emitting almost 25% of all CO_2 emissions (Boden et al., 2015). China is estimated to be the most resource rich country in the world for hydropower and in 2015 produced 1064 TWh, approximately 19% of China's electricity generation. Mapping of China's hydropower resource would be of use to government (national and local), energy supply companies and overseas agencies interested in renewable energy and/or climate change.

China hosts some of the longest rivers in the world. By length, discharge and catchment area, the Yangtze is by far the biggest of these at 6300km, an average discharge at the river mouth of approximately 30,000m^3s^{-1} and a catchment area of approximately 1.9 million km^2. The upper basin of the Yangtze River includes mountain peaks over 6400m and the mountainous terrain is ideal for hydropower resource. The Three Gorges Dam on the middle reaches of the Yangtze is the largest power station in the world.

This project aims to map the Yangtze basin hydropower resource by creating a mathematical model to estimate long-term hydrographs of river flow employing high resolution datasets of precipitation, temperature and evapotranspiration in conjunction with a suitable digital elevation model (DEM). The results of this model can then be investigated to find economically viable hydropower resource and siting of installations considering both run-of-river and impoundment type schemes. Long term hydrographs of ungauged catchments may also be of use for other purposes (e.g. flood control).

2 Methodology

2.1 Selection and Development of Terrain Datasets

A fundamental aspect of assessing potential hydropower is the need to model the underlying terrain and how the water routes over the terrain as it heads towards the catchment outlet. High quality Digital Elevation Models (DEMs) representing most of the Earth's surface are available as a raster (an array of cells) of heights produced using satellite data. The Shuttle Radar Topography Mission (SRTM) DEM at approximately 90m resolution (Farr et al., 2007) is suitable for derivation of watershed boundaries and drainage networks. However, voids in the SRTM could be a problem in hydrological analysis (Ling et al., 2005) hence the derived HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales) DEM dataset was selected for the model due to the hydrological conditioning (or error reduction) applied (Lehner et al., 2008). The HydroSHEDS dataset improves upon the SRTM data through a series of automated procedures including void filling, filtering, stream burning and upscaling techniques with manual corrections where necessary available at 3 arc-second, 15 arc-second (approximately 450m) and 30-arc-second grids. Quality assessments indicate the accuracy of the HydroSHEDS dataset significantly exceeds that of other DEMs for creation of watersheds and river maps. Due to the vast scale of the Yangtze basin and computing power available it was decided to model the terrain using the 15 arc-second dataset.

A flow direction raster defines the direction of flow from each cell to its steepest down-slope neighbour derived using the D8 algorithm (O'Callaghan and Mark, 1984). Using standard GIS techniques the slope and aspect of each cell can be determined and the algorithm assumes water follows the steepest path into one of 8 directions. Flow accumulation is derived from the flow direction raster, and is the sum of cells that would ultimately flow into a downstream cell. The HydroSHEDS river lines dataset determines rivers as those with a catchment of 8km^2 or greater, suitable for some basic initialisation of a model but rivers may form from a smaller catchment size within areas of high precipitation, while in dry areas (such as high on the Qinghai Plateau) larger catchment contribution may be necessary before a river forms. The boundary of the Yangtze drainage basin was determined within ArcGIS using the HydroSHEDS Asia flow accumulation raster by identifying the drainage point (mouth) of the Yangtze River. This enabled a suite of Yangtze-specific datasets including DEM, flow direction, flow accumulation and river network rasters (see Figure 1).

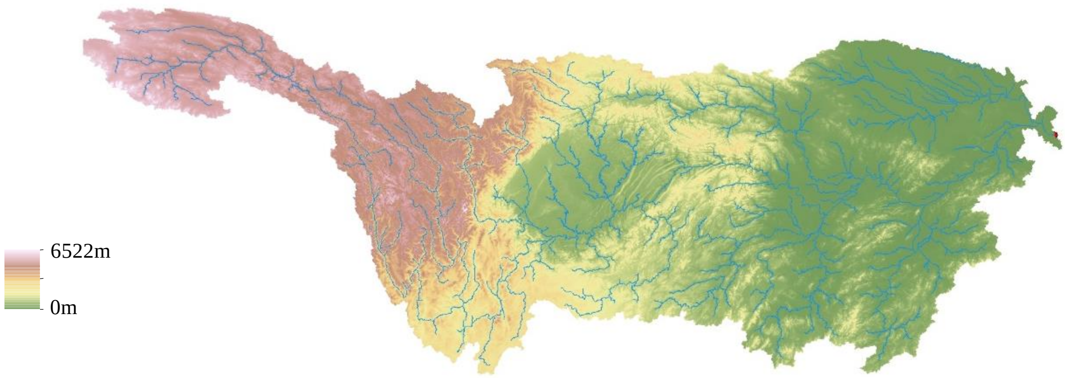


Figure 1: DEM of Yangtze basin with rivers overlaid (large rivers only) (produced using ArcGIS)

Further input datasets determine the starting conditions for the model. A model starting dry could take a significant amount of time to "warm-up" and hence the starting in-soil/ground storage, baseflow and snow conditions were set from the Modern-Era Retrospective Analysis for Research and Applications (MERRA) data suite (Rienecker et al., 2011). For starting overland runoff conditions, the flow accumulation raster was 'weighted' using average long-term overland flow from the Global Runoff Data Centre (GRDC) Composite Runoff Fields dataset produced by the Bundesantalt für Gewasserkunde (BfG) (Fekete et al., 2002). These starting condition datasets are coarse and most likely an over or under estimate of actual conditions but it was felt that this would enable the model to "warm up" faster than if starting conditions were assumed to be completely dry and particularly as it would ensure rivers are flowing from the start. In practice, the model is also ran for a few months in advance of the actual starting month to enable the model to warm-up.

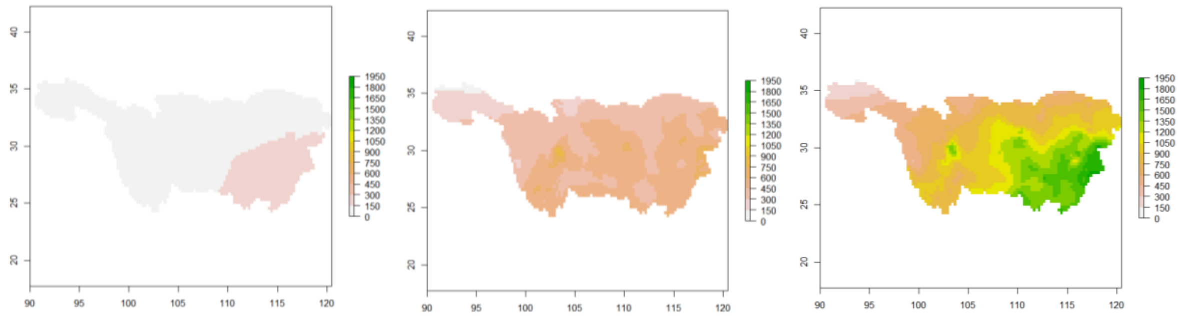
2.2 Selection and Development of Meteorological Datasets

Precipitation and temperature data is another key input to hydrological models and there are a number of gridded meteorological datasets available at various temporal and spatial resolutions covering a significant proportion of the globe (Schneider, 2013). Ideally the data would be both of high spatial and temporal resolution (sub-daily) but most of the sub-daily datasets are limited in their history or global coverage. Hydropower estimation requires long time-series of data. The MERRA data suite holds gridded precipitation and temperature data dating back to 1979 at hourly resolution but is of low spatial resolution. Therefore the Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) precipitation dataset (Yatagai et al., 2012) and temperature dataset (Yasutomi et al., 2011) were selected due to their relatively high spatial resolution (0.25 by 0.25 degrees, ~25km), daily time step and availability from 1973 to 2007 (1950 for the precipitation dataset).

Precipitation data determines the input of moisture into the drainage basin whereas temperature determines whether precipitation falls as snow or rain and also contributes to evapotranspiration rates. The APHRODITE precipitation dataset was created using data from between 5,000 and 12,000 rain gauge stations across Asia and has significantly improved rainfall data for regions such as the Himalayas. The temperature dataset was created from a significant number of observation stations, up to 3 times the number within the Global Telecommunication System used for the creation of most other datasets of this nature. Temperature is compensated by the standard adiabatic lapse rate due to the difference in height of the DEM and the average heights of the temperature dataset.

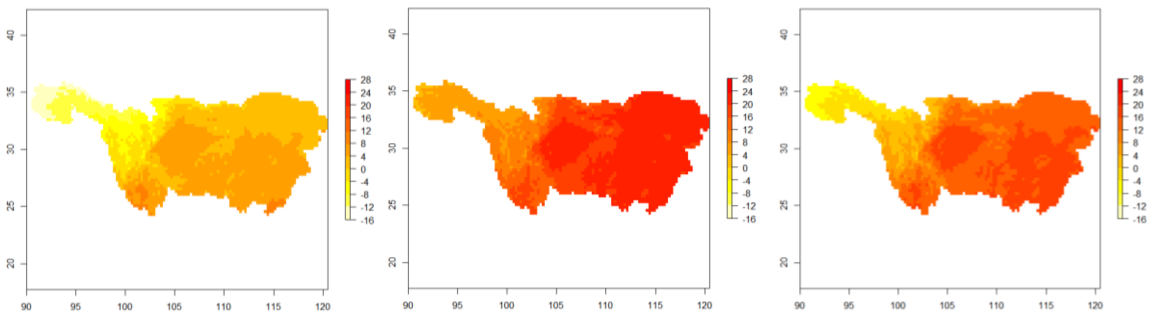
Evapotranspiration accounts for loss of water due to evaporation from land and water bodies to the atmosphere together with plant transpiration (movement of water within plants and loss of vapour from leaf stomata). A daily dataset from 1979 to 2007 was created (by this project) using MERRA data employing the Food and Agriculture Organisation (FAO56) method based on the Penman-Monteith equation (Allen et al., 2006). Contributing MERRA datasets include daily maximum and minimum temperatures, daily maximum and minimum specific humidity at 2m above displacement height, mean air pressure, northerly and easterly windspeed, leaf area index, displacement height, net surface downward shortwave radiation flux, albedo fraction and emitted and absorbed longwave radiation at the surface.

Note that to date there has been no attempt made to account for diurnal changes in meteorological conditions within the model and assumes temperature is constant throughout each day and hourly precipitation and evapotranspiration is 1/24th of the daily amount. Meteorological datasets with a higher temporal resolution (i.e. sub daily) would improve the model. The plots in Figures 2 and 3 show the annual, summer and winter average precipitation and temperature for 1979 to 2007. Summers in the Yangtze are categorized by high levels of precipitation and warm temperatures whereas winters are cool and dry, particularly so in the western portion of the catchment.



Winter mean 82mm *Summer mean 432mm* *Annual mean 954mm*

Figure 2: Winter (Jan-Mar), summer (Jul-Sep) and annual mean precipitation in the Yangtze drainage basin 1979 – 2007 using APHRODITE data (Yatagai et al., 2012)



Winter mean 1.6°C *Summer mean 17.2°C* *Annual mean 11.7°C*

Figure 3: Winter (Jan-Mar), summer (Jul-Sep) and annual mean temperature in the Yangtze drainage basin 1979 – 2007 using APHRODITE data (Yasutomi et al., 2011)

Although only over a relatively short period of time (1979-2007), analysis of the rolling 12-month average precipitation and temperature shows a slight decreasing trend in precipitation and a pronounced increasing trend in temperature (*see figure 4*) – possibly due to the impact of climate change. This may result in future increased evapotranspiration, and a change in the snow regime, which could have a long-term impact on the hydropower resource.

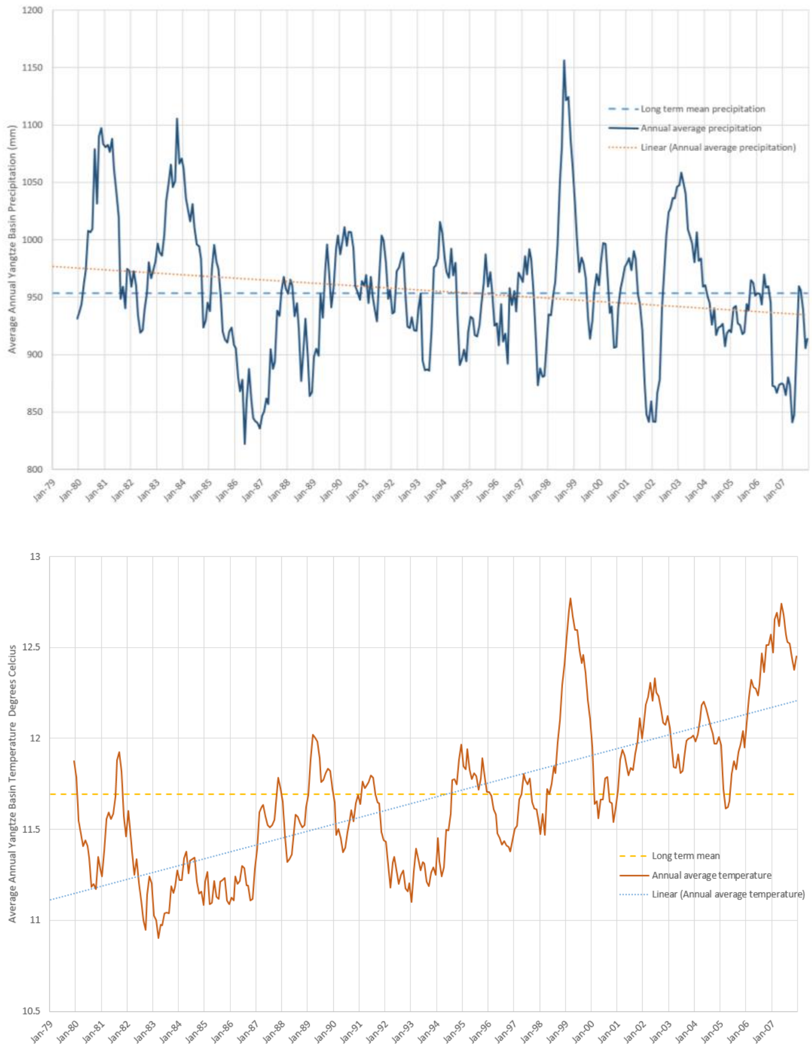


Figure 4: Trends in average annual precipitation (top) and temperature (below) in the Yangtze basin between 1979- 2007 using APHRODITE data (Yatagai et al., 2012; Yasutomi et al., 2011)

2.3 Inclusion of a Snowmelt Model

Temperature index models or degree day snowmelt models are often employed within runoff models, assuming a relationship between air temperature and melt when above a threshold temperature: the degree day factor. However, this melt factor is not constant and can vary spatially and seasonally and hence there has been a gradual transition towards energy-balance models (Hock, 2003). This hydrological model employs the widely quoted National Weather Service River Forecast/Snow Accumulation and Ablation Snow-17 model (Anderson, 1973; Anderson 2006). Snow-17 is a conceptual model incorporating most of the physical processes that take place within snow cover but only in a simplified form. Despite its sophistication there is no data to calibrate this snow model against and therefore standard initialisation parameters have been used. Furthermore, it is computationally time expensive when running in catchments the size of the Yangtze and therefore a simpler model may be considered in the future.

2.4 An overview of the grid based hydrological model

Building on a study of Scotland's hydropower resource (Duncan, 2014), the distributed Grid-to-Grid (G2G) model (Bell et al., 2007) was selected to simulate how water flows across the terrain due to its ease of integration with grid based datasets and proven ability to simulate flows at high resolution, although admittedly only in the UK thus far. The equations employed in the G2G model are used to determine the runoff production and routing algorithms of this model, built using R code integrating the datasets previously discussed, with some of the flow routing coded in C++, and versions built for both Linux and Windows.

After some initialisation and loading of input datasets, daily meteorological files are loaded into the model at the start of each day's simulation, spatially modified to the model's resolution discussed and the precipitation and potential evapotranspiration found. Within each grid square a water balance is maintained with each cell having a finite store related to the topographic gradient (shallow gradients permit greater storage capacity), with excess water forming runoff (a fast surface kinematic wave). Drainage from the store adds to baseflow (a slow subsurface kinematic wave) and return flow links the baseflow to the surface runoff. Routing of the runoff is based on the kinematic wave approximation of the St. Venant equations for gradually-varying flow in open channels. An additional layer of complexity is added to simulate real hill slope conditions by integrating the Probability Distributed Soil-Moisture formulation (Moore, 1985) and assumes a certain proportion of the grid square is saturated and generating runoff even when rainfall amounts are small – otherwise the whole grid square would have to be saturated before runoff was produced. The surface/subsurface wave speeds and return flow rates (which can differ for land and river), the drainage rate and maximum cell storage form a set of parameters that require calibration and optimisation.

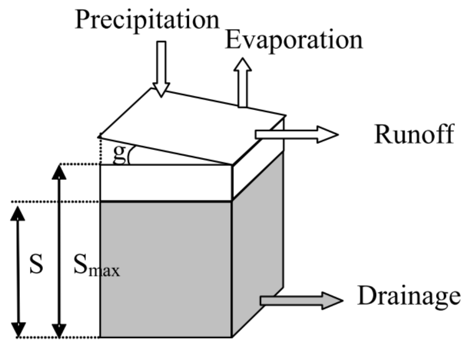


Figure 5: Overview of the G2G model grid-box storage illustrating components of the water balance (Bell et al., 2007)

2.5 Running the code, calibration and outputs

The code can be run over any time period between January 1979 and December 2007 and with a specific set of parameters or in calibration mode employing Differential Evolution (Storn and Price, 1997). Differential evolution optimises the objective function comparing results from the simulated flow at the catchment outlet to observed flows by sampling a wide parameter space. New candidate solutions are combined with existing solutions keeping solutions with the best score or fitness. A number of objective functions for hydrological model assessment (Krause et al., 2005) are built into the model with only one objective function selected at any one time (typically Nash Sutcliffe efficiency). As timing issues with respect to the input data could reduce objective function results when comparing daily and simulated daily discharge, the catchment flow duration curves (FDC) are compared in the calibration. Ultimately, it is the flow duration curve that is important in hydropower assessment.

Calibration data is publicly available for a small number of rivers of various catchment sizes within the Yangtze from the GRDC river discharge data (GRDC, 2015), although there are only 12 such points in the Yangtze catchment which is nearly 2 million km^2. Calibration requires hundreds/thousands of model runs trialling different parameters within the model space but large catchments require significant computing time for each run. Hence, calibration is carried out on smaller catchments with the premise that these calibration parameters will hold for larger catchments. To speed up the calibration process the code is run in parallel on the University of Edinburgh EDCF Linux Compute Cluster. Once calibrated, the model is run with an optimal set of parameters with the hourly and daily flow recorded across the catchment and saved as daily raster files from which the modelled FDC percentile flow is obtained. The river network and the flow duration rasters feed into the hydropower search.

2.6 Testing the model

Testing of the model was carried out on the catchment above the Laoguan He (Laoguan River) Xixia monitoring station – a 3205km^2 catchment (*see figure 6*). The catchment is on the northern boundary of the Yangtze drainage basin with the drainage point approximately 265km from the Yangtze itself and 840km from the mouth. Calibration was carried out over 12 months starting in January 1979 with two warm-up months, with the best performing parameter sets ran again from 1979 to 1992 (the full length of the observation data). The best performing parameter set was then selected to run from 1979 to 2007.

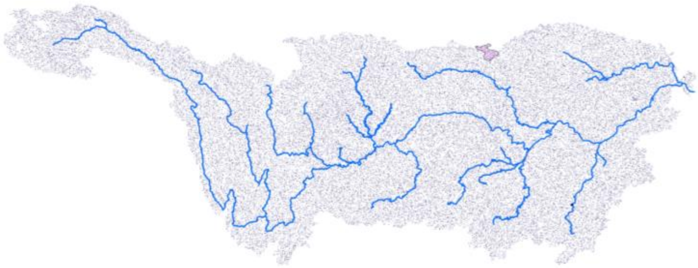


Figure 6: Location of the Laoguan He catchment for testing the model (pink shade)

2.7 Hydropower search

The hydropower search is still in development. The proposed methodology is to place points at intervals across the river network found through hydrological modelling and extend a 'virtual penstock' to points downstream. By trialling various penstock diameters, and design flows, and employing the flow duration curve percentile rasters, a number of iterations can be costed. Economically viable configurations will be extracted and mapped.

3 Results

Over a two-week period, 1588 model runs for the year 1980 were performed on the Laoguan He Xixia catchment. Results with a total modelled runoff volume of between 75% and 125% of the observed runoff volume at the catchment outlet were retained for further analysis. These were sorted by each of the objective functions and the top 5 performing parameter sets for each again kept for further analysis, resulting in approximately 40 parameter sets. The FDC curves and daily flow plots were inspected visually and the best 5 selected for a longer calibration run (1979 to 1992). Of the 11 objective functions tested the results ranged from 0.715 to 0.993, and 8 of the 11 had a result greater than 0.95. Only the modified form of the Nash Sutcliffe efficiency and the Nash Sutcliffe efficiency using logarithmic values had a result less than 0.9 (0.822 and 0.715 respectively), which are both designed to increase the sensitivity of low flow values. Once again, the best performing parameter set during the longer calibration was selected for the full length model run (1979 to 2007).

Example Screenshots during running of the model are shown overleaf in *Figure 7*:

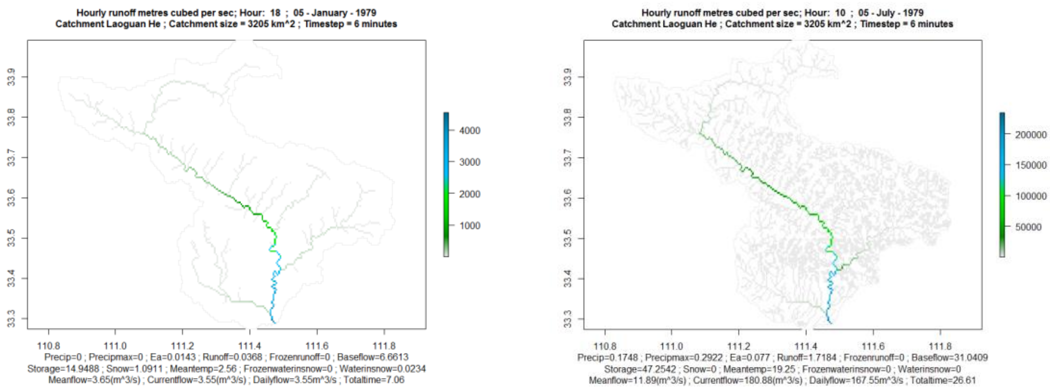


Figure 7: Example screenshots during running of the model showing surface runoff (l/s) (only > 5l/s shown) in January (left) and July (right)
(Values below the plot are catchment averages in mm except for temperature (°C), time (mins) and flow (m^3s^{-1}))

At the end of a calibration run a daily flow plot and an FDC curve are generated showing the modelled data in red and the observed data in green. *Figure 8* (1980 only) and f*igure 9* (1979 to 1992) show the modelled and observed data for daily flow and the FDC.

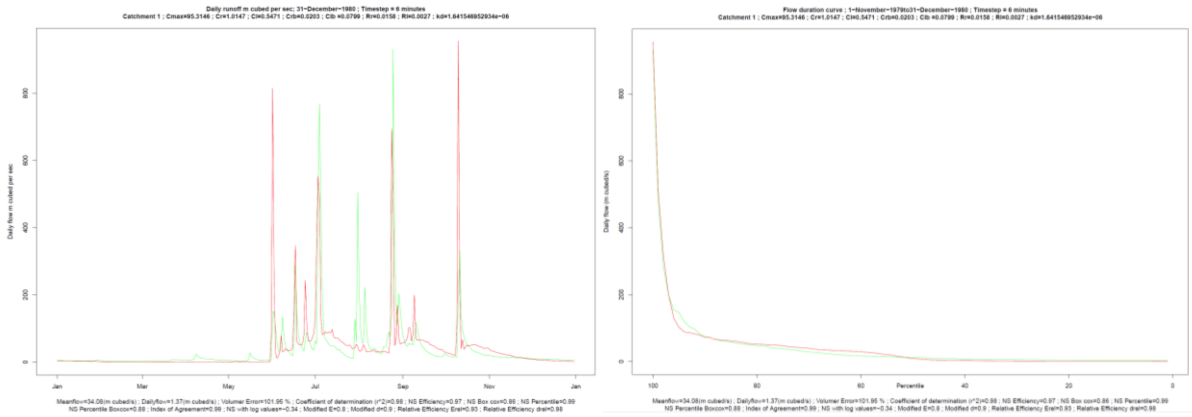


Figure 8: (Left) Modelled (red) and observed (green) daily surface runoff and (Right) modelled (red) and observed (green) flow duration curve – both for 1980 using the optimised parameter set at the Laoguan He Xixia catchment outlet

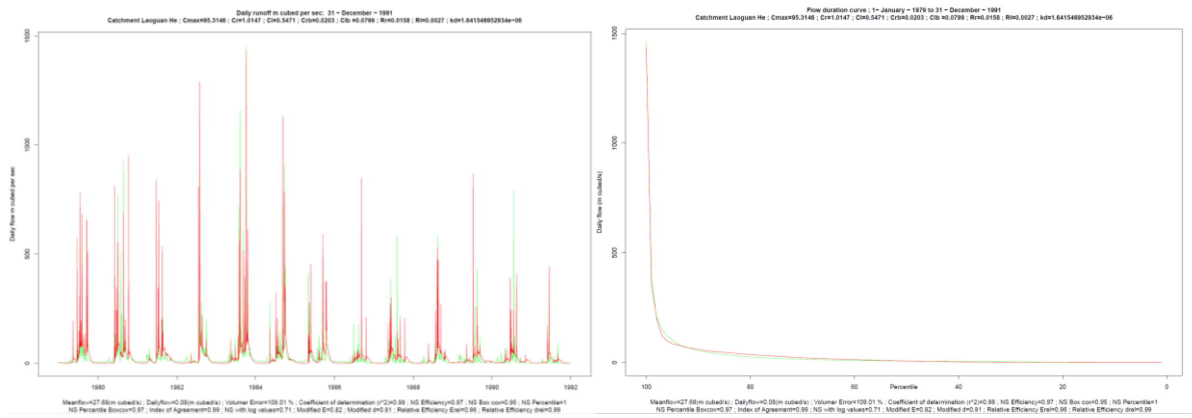


Figure 9: (Left) Modelled (red) and observed (green) daily surface runoff and (Right) modelled (red) and observed (green) flow duration curve – both for 1980 using the optimised parameter set at the Laoguan He Xixia catchment outlet

The 1979-2007 daily flow and FDC curves using the optimised parameter set for the Laoguan He Xixia catchment is shown below in *Figure 10*:

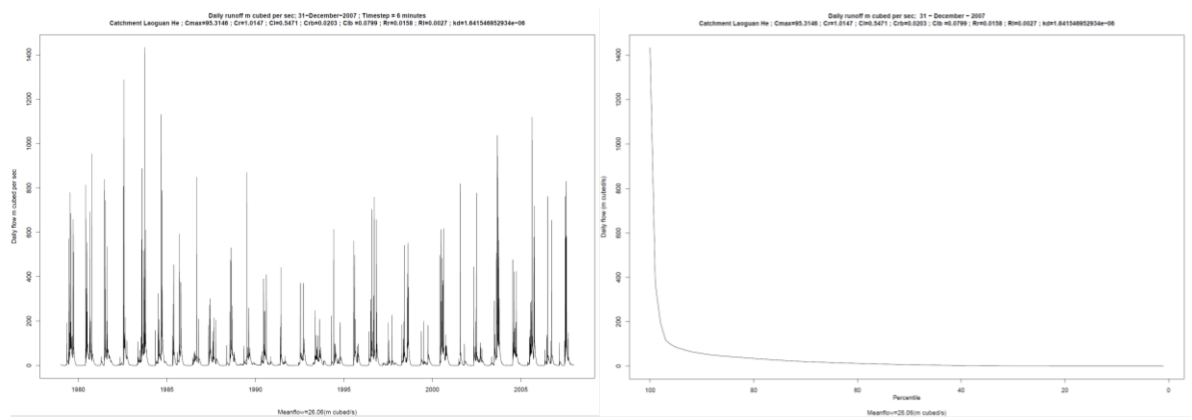


Figure 10: (Left) Screen plot of the full 1979 to 2007 daily surface runoff (modelled data only) and (Right) screen plot of the full 1979 to 2007 flow duration curve (modelled data only) for the Laoguan He Xixia catchment using the optimised parameter set – units m^3s^{-1}

Combing the daily flow enables the percentile values at each point in the catchment to be extracted: examples for 100th, 50th and 5th percentile plots (or Q0, Q50, Q95) are shown in *Figure 11:*

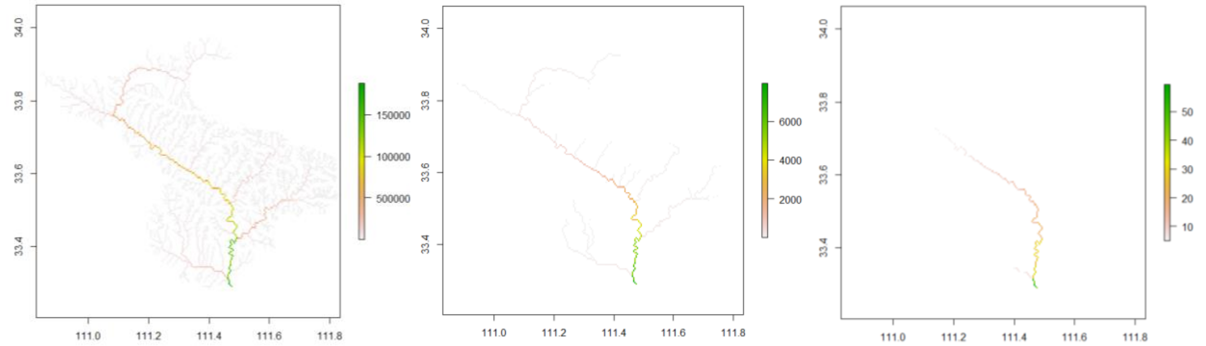


Figure 11: Modelled 100th percentile (Q0) (left), 50th percentile (Q50) (middle) and 5th percentile (Q95) (right) surface runoff data for the Laoguan He Xixia catchment (3205km²) from 1979 to 2007 (for flow >5l/s) (units l/s)

4 Conclusions

Renewable technologies are of ever increasing importance due to both energy requirements and climate change, particularly in countries such as China where there has been massive economic growth. Mapping of hydropower in basins such as the Yangtze would be useful to agencies internal and external to China, and the techniques employed transferable to other catchments around the world as the input data is global and accessible. The model developed has been shown to correlate well compared to observed data with high-performing results across a number of objective function types, particularly relating to the FDC. However, there are errors and simplification within both the input and observed data and these need to be examined more closely. A strategy needs to be developed on how the results from small sub-catchments, such as Laoguan He Xixia, can be used to model the hydrology of the whole Yangtze catchment as computing resources are limited. The resulting percentile flow rasters are easily integrated into a hydropower search methodology.

References

Allen, R.G., W.O. Pruitt, J.L. Wright, T.A. Howell, F. Ventura, R. Snyder, D. Itenfisu, P. Steduto, J. Berengena, J.B. Yrisarry, M. Smith (2006), A recommendation on standardized surface resistance for hourly calculation of reference ETo by the FAO56 Penman-Monteith method. *Agricultural Water Management*, **81**(1): 1-22.

Anderson, E.A. (1973), SNOW–17 a model based on temperature and precipitation. *National Oceanic and Atmospheric Administration (NOAA)*, publication SW-102, Washington DC, USA.

Anderson, E.A. (2006), Snow Accumulation and Ablation Model – SNOW-17. *National Oceanic and Atmospheric Administration (NOAA) / National Weather Service,* Washington DC, USA.

Bell, V.A., A. Kay, R. Jones, R. Moore (2007), Development of a high resolution grid- based river flow model for use with regional climate model output. *Hydrology and Earth System Sciences*, **11**(1):532–549.

Boden, T.A., G. Marland, R.J. Andres (2015), Global, Regional, and National Fossil-Fuel CO_2 Emissions. *Carbon Dioxide Information Analysis Center*, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. doi 10.3334/CDIAC/00001_V2015

British Petroleum (2015), Statistical Review of World Energy 2015. British Petroleum, London, UK.

Duncan, N. (2012). Mapping the Hydropower Resource of Scotland. Ph.D. Thesis. Edinburgh University, UK.

Farr, T.G, P.A. Rosen, E. Caro, R. Crippen., R. Duren; S. Hensley; M. Kobrick, M.Paller, E. Rodriguez, L. Roth, D. Seal, S. Shaffe, J.Shimada, J. Umland, M. Werner, M. Oskin, D. Burbank, D. Alsdorf (2007), The Shuttle Radar Topography Mission. *Reviews of Geophysics* **45** (2): RG2004. doi:10.1029/2005RG000183

Fekete, B., C. Vörösmarty, W. Grabs (2002): Global composite runoff fields on observed river discharge and simulated water balances. Water System Analysis Group, University of New Hampshire, and Global Runoff Data Centre. Koblenz, Germany: Federal Institute of Hydrology (BfG).

GRDC (2015), River Discharge Data. The Global Runoff Data Centre, Federal Institute of Hydrology (BfG), 56068 Koblenz, Germany

Hock, R. (2003), Temperature index melt modelling in mountain areas. *Journal of Hydrology* **282**(1): 104-115.

Krause, P., D. P. Boyle, and F. Bäse (2005), Comparison of different efficiency criteria for hydrological model assessment. *Advances in Geosciences* **5**: 89-97.

Lehner, B., K. Verdin, A. Jarvis (2008), Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales - New global hydrography derived from spaceborne elevation data. *Eos, Transactions, AGU*, **89**(10): 93-94.

Ling, F., Q. W. Zhang, and C. Wang (2007), Filling voids of SRTM with Landsat sensor imagery in rugged terrain. *International Journal of Remote Sensing* **28**(2): 465-471.

O'Callaghan, J.F. and D.M. Mark (1984), The extraction of drainage networks from digital elevation data. *Computer Vision, Graphics, and Image Processing*, **28**(3):323–344. ISSN 0734189X. doi:10.1016/S0734-189X(84)80011-0.

Paish, O. (2002). Small hydro power: technology and current status. *Renewable and sustainable energy reviews*, **6**(6): 537-556.

Rienecker, M.M., M.J. Suarez, R. Gelaro, R. Todling, J. Bacmeister, E. Liu, M.G. Bosilovich, S.D. Schubert, L. Takacs, G.-K. Kim, S. Bloom, J. Chen, D. Collins, A. Conaty, A. da Silva, et al. (2011). *MERRA: NASA's Modern-Era Retrospective Analysis for Research and Applications. J. Climate*, **24**: 3624-3648, doi:10.1175/JCLI-D-11-00015.1

Schneider D.P., C. Deser, J. Fasullo, K.E. Trenberth (2013), Climate Data Guide Spurs Discovery and Understanding. *Earth and Space Science News,* **94** (13): 121-122.

Storn, R. and K. Price (1997). Differential Evolution – A simple and effective heuristic for global optimization over continuous spaces. *Journal of Global Optimization*, **11:**341-359.

Yasutomi, N., A. Hamada, A. Yatagai (2011), Development of a long-term daily gridded temperature dataset and its application to rain/snow discrimination of daily precipitation, *Global Environmental Research*, **V15N2**:165-172.

Yatagai, A., K. Kamiguchi, O. Arakawa, A. Hamada, N. Yasutomi, A. Kitoh (2012), APHRODITE: Constructing a Long-term Daily Gridded Precipitation Dataset for Asia based on a Dense Network of Rain Gauges. *Bulletin of American Meteorological Society*, doi:10.1175/BAMS-D-11-00122.1.

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